ESTIMATION OF INHALATION RATES FOR U.S. CHILDREN: UPDATE TO THE DEFAULT VALUES FOR THE INTEGRATED EXPOSURE UPTAKE BIOKINETIC MODEL FOR LEAD IN CHILDREN

OVERVIEW

Since 1994, the Office of Solid Waste and Emergency Response (OSWER) has recommended the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK model) as a risk assessment tool to support environmental cleanup decisions at residential sites (U.S. EPA, 1994a,b). The IEUBK model uses empirical data from numerous scientific studies of lead uptake and biokinetics, contact and intake rates of children with contaminated media, and data on the presence and behavior of environmental lead to predict a plausible distribution or geometric mean (GM) of blood lead (PbB) for a hypothetical child or population of children.[1] The relative variability of PbB concentrations around the GM is defined as the geometric standard deviation (GSD). The GSD encompasses biological and behavioral differences, measurement variability from repeat sampling, variability as a result of sample locations, and analytical variability.[2] From this distribution, the IEUBK model estimates the risk (*i.e.*, probability) that a child's or a population of children's PbB concentration will exceed a certain level of concern (recorded as "$P_{\text{level of concern}}$") as currently established at 10 micrograms per deciliter (µg/dL) (U.S. EPA, 1998, 1994a; White et al., 1998).

The default background values for the *Inhalation Rate* parameter in the IEUBK model represent age-specific central tendency estimates for the inhalation rates for children ([redacted] of age) in U.S. These values were designed to represent a combination of physiological considerations including age, body size, lung capacity, and activity of the child, paired with a time- and activity-based regression analysis (U.S. EPA, 1994a, 1989; Phalen et al., 1985; Nutrition Foundation, 1982; ICRP, 1975; Altman and Dittmer 1972, 1971). Briefly, Phalen et al. (1985) paired male and female body mass data from Altman and Dittmer (1972, 1971) with inhalation rates associated with three levels of physical exertion (*i.e.*, low, light and heavy) to determine time-weighted inhalation rates.[3] U.S. EPA (1989) later combined the results from Phalen et al. (1985) with data from the Nutrition Foundation (1982) and the International Commission on Radiological Protection (1975) to construct age-specific daily inhalation rates. U.S. EPA (1994a) matched these inhalation rates into the age categories in the IEUBK model.

The purpose of this document is to provide a recommendation for revising the *Inhalation Rate* parameter in the IEUBK model using: 1) more representative inhalation rate data for children, and 2) a more representative methodology for estimating childhood inhalation rates in the U.S. The proposed estimates for the *Inhalation Rate* parameter in the IEUBK model are based on energy expenditure data available from the Institute of Medicine's (IOM) doubly-labeled water (DLW) dataset (IOM, 2005) and

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[1]The GM represents the central tendency estimate (*e.g.*, mean, [redacted]th percentile) of PbB concentration of children from a hypothetical population (Hogan et al., 1998). If an arithmetic mean (or average) is used, the model provides a central point estimate for risk of an elevated PbB level. By definition a central tendency estimate is equally likely to over- or under-estimate the lead-intake at a contaminated site.Upper confidence limits (UCLs) can be used in the IEUBK model; however, the IEUBK model results could be interpreted as a more conservative estimate of the risk of an elevated PbB level. See U.S. EPA (1994a) for further information.

[2]The IEUBK model uses a log-normal probability distribution to characterize this variability (U.S. EPA, 1994a). The biokinetic component of the IEUBK model output provides a central estimate of PbB concentration, which is used to provide the geometric standard deviation (GSD). The GSD encompasses biological and behavioral differences, measurement variability from repeat sampling, variability as a result of sample locations, and analytical variability. In the IEUBK model, the GSD is not intended to reflect variability in PbB concentrations where different individuals are exposed to different media concentrations of lead. The recommended default value for GSD ([redacted]) was derived from empirical studies with young children where both blood and environmental lead concentrations were measured (White et al., 1998).

[3]Based on data from a series of experiments with tracheobronchial casts, Phalen et al. (1985) formulated regression equations to compute tracheobronchial dimensions as a function of individual body height. Phalen et al. (1985) was then able to predict inhalation rates and particle deposition based on body mass. Values for newborns, infants, children, and adolescents were scaled downward as linear functions of body mass (Phalen et al., 1985).

the linear equations developed by Brochu et al. (2006) and Layton (1993) to convert metabolic energy to inhalation rates (Table 1).

Table 1. Comparison of age-specific inhalation rates (m^3/day) for use in the IEUBK model.

Source	Age Category ([redacted])							Basis for Age-Specific Value
	[redacted]							
IEUBK Model Default[a]	[redacted]							Methodology U.S. EPA, 1994b, 1989; Phalen et al., 1985 Time- and activity-based estimates Data Source Altman and Dittmer 1971, 1972 ICRP, 1975 Nutrition Foundation, 1982
Proposed Inhalation Rates[b]	[redacted]							Methodology Stifelman, 2007; Brochu et al. 2006; Layton, 1993 Total energy expenditure (DLW method) Data Source IOM, 2005

ICRP: International Commission on Radiological Protection; IOM: Institute of Medicine; DLW: doubly-labeled water
[a]IEUBK model v. 1.1, build 11.
[b]Mid-point inhalation rates are provided in the table for comparative purposes only, the proposed update to the IEUBK model will use the estimated regression equation to calculate inhalation rate as a continuous non-linear function of age (see Tables 5 and 6).

This document provides the technical basis for updating for the *Inhalation Rate* parameter in the IEUBK model. The intended audience is risk assessors familiar with the IEUBK model. For more information on the use of the IEUBK model in Superfund lead risk assessment, refer to U.S. EPA (1994a) or the Technical Review Workgroup for Lead (TRW) website (http://epa.gov/superfund/lead/trw.htm).

INTRODUCTION

The IEUBK model predicts PbB concentrations in children ([redacted] of age) exposed to lead from several sources and routes (U.S. EPA, 1994a). The IEUBK model uses more than [redacted] input parameters that are initially set to default values. Of these many input parameters, there are [redacted] external input parameters that may be changed by the user; the remainder are locked (U.S. EPA, 1994a). Default values represent national averages or plausible central values for pooled male and female children that were derived from: a) empirical data in the open literature that include values for the lead concentrations commonly found in the various media and diet, b) intake rates such as the soil/dust ingestion rate, and c) exposure durations (White et al., 1998). The representativeness of the IEUBK model output is dependent on the representativeness of the data (often assessed in terms of: completeness, comparability, precision, and accuracy [U.S. EPA, 1994a]).

Site-specific data are essential for risk assessment support for developing cleanup goals. Because there may be potentially important differences among sites, using representative site- and community-specific information that reflects exposure conditions at the site will improve the accuracy of the IEUBK model predictions. The most common type of site-specific data are exposure point concentrations for air, water, soil, and dust. Such data are typically collected as part of the site characterization. Receptor

information related to intake rates (breathing rate; soil and dust contact rate) is not typically collected on a site-specific basis.

To promote defensible and reproducible risk assessments and clean-up plans while maintaining flexibility which is necessary to respond to different site conditions, U.S. EPA recommends the Data Quality Objectives (DQOs) process (U.S. EPA, 2006). DQOs provide a structured approach to collecting environmental data that will be sufficient to support decision-making: http://www.epa.gov/QUALITY/dqos.html.

Inhalation rate is dependent on age, sex, body size, health status, lung capacity, altitude, and activity patterns (U.S. EPA 2008, 1989; Layton, 1993). Infants and children have a higher resting metabolic rate and oxygen consumption rate per unit of body weight than adults due to their rapid growth and lung surface area (U.S. EPA, 2008). Historically, time- and activity-based methods have been used to calculate inhalation rates (U.S. EPA, 1994b, 1989); however, a growing body of evidence supports estimating inhalation rates as a function of individual energy expenditure (EE), or the amount of oxygen required for the metabolic conversion of dietary nutrients (U.S. EPA, 2009b, Layton, 1993). Individual EE data can be used to characterize both short- and long-term inhalation rates using two approaches: 1) average daily intakes of food energy from dietary surveys, adjusted for under reporting of foods, and 2) average daily energy expenditure calculated from ratios of total daily expenditure (TEE) to basal metabolic rates (BMR).

CALCULATING ENERGY EXPENDITURE

AVERAGE DAILY INTAKES OF FOOD ENERGY (DIETARY SURVEY)

Energy expenditures have historically been estimated using food-energy intake data obtained from nationwide food intake surveys (U.S. EPA, 2011, 2010, 2009a,b, 2008, 1997; Arcus-Arth and Blaisdell, 2007; Layton, 1993). Initially, Layton (1993) utilized food-energy intake data from the U.S. Department of Agriculture's 1977-1978 National Food Consumption Survey (NFCS; USDA, 1984) and the U.S. Department of Health and Human Services 1976-80 National Health and Nutrition Examination Survey (NHANES; US DHHS, 1983) to estimate weighted average oxygen uptakes ([redacted]) (Table 3 and 4). More recently, U.S. EPA (2011, 2009a) provided recommendations for long-term ([redacted] days) inhalation rates based partly on the indirect measure of inhalation rates derived from dietary and activity survey responses obtained from the 1994-1996 and 1998 USDA Continuing Survey of Food Intake for Individuals surveys (CFSII).[4]

It should be noted, however, that while dietary data are intended to capture everything that is consumed within a specified timeframe, there are a variety of variables (*e.g.*, age, sex, socioeconomic status, ethnic considerations) or individual behaviors (*i.e.*, not reporting foods that are "perceived to be bad or sinful" including pies, fried foods, sugars) that bias toward under reporting on dietary surveys (IOM, 2005). Layton used a bias correction factor of 1.2 to adjust the total energy intake calculated from dietary surveys (Layton, 1993). Layton's approach is further outlined in U.S. EPA (1997).

[4]Dietary survey repsonses were based on self-reported dietary data and used to estimate inhalation rates for children from [redacted] of age (n=[redacted]) (as reported by Arcus-Arth and Blaisdell, 2007).

Table 2. Comparisons of estimated basal metabolic rates with average food-energy intakes for individuals sampled in the 1977-1978 National Food Consumption Survey (USDA, 1984).

Cohort/Age (years)	Body Weight (kg)	Basal Metabolic Rate		Energy Intake		Ratio
		MJ/day	kcal/day	MJ/day	kcal/day	EFD/BMR
[redacted]						

Source: Layton (1993).

Table 3. Daily inhalation rates estimated from the food-energy intakes for cohorts sampled in the 1977-1978 National Food Consumption Survey (USDA, 1984) and estimated inhalation rates for active and inactive respondents[d].

Cohort/Age (years)	L[c]	Daily Inhalation Rate[a] (m^3/day)	Sleep (hours)	Metabolic Equivalent		Inhalation Rates[b] (L/min)	
				A	F	Inactive	Active
[redacted]							

[a]Daily inhalation rate is calculated by multiplying the EFD values in Table 2 by [redacted] for those under [redacted] years.
[b]Inhalation rate for inactive periods is calculated as [redacted] /min) and for active periods it is computed by multiplying the inactive inhalation rate by F. Values of EFD and BMR are from Table 2.
[redacted]" represents the number of years for each cohort. The lifetime averages were computed by multiplying the individual inhalation rates by the respective "L" values, summing the products across cohorts, and dividing the result by [redacted], the total of the cohort age spans.
[d] The inactive rates are near the [redacted] percentile in Brochu et al. (2006) paper, but the active rates exceed the [redacted] percentile.
Source: Layton (1993); also cited in U.S. EPA (1997).

TOTAL ENERGY EXPENDITURE (DOUBLY-LABELED WATER METHOD)

According to the Institute of Medicine (2005), total daily energy requirements and expenditures (TEE) are a function of the dietary intake, physical activity, thermoregulation, and the energy required for homeostasis (*e.g.*, depositing new tissues and in producing milk). These values can be accurately measured using the DLW method (Speakman, 1998). The DLW method measures daily metabolic activity based on the administration and rate of disappearance of two stable forms of labeled water: deuterium labeled (^2H_2O) and 18-oxygen labeled ($H_2{}^{18}O$) (Stifelman, 2007; Brochu et. 2006; Layton et al. 1993).[5] These disappearance rates can be used to calculate both water flux and CO_2 respiration rates in the body. In addition to dietary information, the calculated CO_2 rates can be used to calculate TEE.

In 2005, the Institute of Medicine compiled a database of DLW energy expenditure. This database incorporated ethnicity, ages, heights, weights, BMRs, physical activity levels, and TEEs for healthy children in the U.S. (ages [redacted]) and adults (ages [redacted]. The DLW database represents energy expended over a long period of time (*e.g.*, weeks) by people engaged in their usual daily activities, rather than from short-term staged activities, resulting in a more reliable measure of actual activity (Stifelman, 2007).

[5]While the disappearance of ^2H_2O is an index of total water flux in the body (*i.e.*, urine, saliva, or blood samples), the disappearance of $H_2{}^{18}O$ is equivalent to the water flux plus the generation of CO_2 from respiration (Stifelman, 2007; Brochu et al., 2006; IOM, 2005).

In 2009, U.S. EPA (2009b) compared the results of dietary survey-derived inhalation rates (Arcus-Arth and Blaisdell, 2007) to results using the DLW method (Butte et al. 2000; Black et al. 1996; Torun et al. 1996).U.S. EPA (2009b) found that the DLW method is the most accurate measurement of the daily TEE, which is necessary for the estimation of daily inhalation rates. DLW energy data are recognized as the gold standard for energy expenditure and an improvement over inhalation rate estimates based on dietary recall or activity-based survey data (Lamonte and Ainsworth, 2001; Burrows et al., 2010) for the following reasons (Stifelman, 2007):

1) the database is robust;
2) they are direct biological measures (survey bias and recall errors are avoided);
3) subjects are free-living; and
4) the observation period of one to two weeks is significantly longer (reduces effect of transient changes in activity patterns) than what is possible from staged activity measures or survey data.

TECHNICAL ANALYSIS

Inhalation rates were calculated using the TEE approach described by Layton (1993), Brochu et al. (2006), and Stifelman (2007). Information on TEE was extracted from the IOM (2005) DLW database. Data for 957 children (ages [redacted] years) were provided in the IOM (2005) dataset. All of the data for children (younger than [redacted] of age) were retained for this analysis. Data for males and females were pooled for average body mass index.[6] Inhalation rates were calculated using the following equation (adapted from Layton, 1993):

$$I_R = E \times H \times I_{EQ}$$

Where:

I_R = Inhalation rate (L/minute) ([redacted] L/min = [redacted] m^3/day)
E = Energy expenditure rate (kJ/day)[7] ([redacted] kJ/day = [redacted] kcal/day)
H = Volume of O_2 in liters consumed per energy expended (constant value equal to [redacted] L O2/kJ or [redacted] L O2/kcal)[8]
I_{EQ} = Inhalation equivalent ratio of I_E to VO_2 (unitless; constant rate equal to [redacted])[9]

[6]Results indicated estimated inhalation rates to be parallel and [redacted]% greater in males than females. However, the TRW Lead Committee does not believe there is sufficient information for all lead exposure and biokinetic variables nor is there necessarily a need to model sex-specific information for typical Superfund site-specific risk assessments.

[7]Layton (1993) noted that inhalation rates for long- and short-term exposures are calculated as a function of energy expenditures that are multiples of the BMR, however, long-term exposures can also be derived from dietary studies that include data on food-energy intakes or the minimal amount of energy required to support basic cellular respiration (as determined by body mass index).

[8]The oxygen uptake factor is the reciprocal of the energy yield of oxygen consumption and equals [redacted], [redacted] and [redacted] L O_2/kJ for carbohydrates, fats, and protein, respectively (Layton, 1993). Layton (1993) estimated the weighted average oxygen uptake (L O_2/kJ) based on data from the 1977-1978 Nationwide Food Consumption Survey (NCFS) (USDA, 1984) and the National Health and Nutrition Examination Survey (NHANES) (U.S. DHHS, 1983).

[9]Individual variability reflects variations in oxygen uptake efficiency, lung physiology, and metabolic efficiency (Layton, 1993).

SAS® software (Version 9.3) was used to estimate daily inhalation rates as a function of age using the following non-linear regression equation:

$$I_R = a \times y^b$$

Where:

I_R = Inhalation Rate (m^3/day)
a = Unitless parameter of the nonlinear regression model estimated by nonlinear lest squares
y = Total Energy Expenditure (based on Layton's approach)
b = Unitless parameter of the nonlinear regression model estimated by nonlinear lest squares

Parameters 'a' and 'b' were determined by nonlinear least squares. Mid-point inhalation rates are provided for comparative purposes only (see Table 4). The proposed update to the *Inhalation Rate* parameter in the IEUBK model will use the estimated regression equation to calculate inhalation rate as a function of age (Tables 5, 6 and Figures 1, 2). The resulting values for inhalation rates are similar to those reported by Kawahara et al. (2011) for [redacted]-year old Japanese children ([redacted] m^3/day vs. [redacted] m^3/day, respectively). For comparative purposes, estimates of other inhalation rate studies that were calculated for this review using linear interpolation are provided in Table 7.

Table 4. Summary of proposed IEUBK model inhalation rates.

IEUBK Model Age Group	Age Midpoint (years)	Parameter		Proposed IEUBK Model I_R (m^3/day)
		a	b	
[redacted]	0.5	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]			[redacted]
[redacted]	[redacted]			[redacted]
[redacted]	[redacted]			[redacted]
[redacted]	[redacted]			[redacted]
[redacted]	[redacted]			[redacted]
[redacted]	[redacted]			[redacted]

I_E: Inhalation rates
[a]Values in parenthesis represent lower and upper confidence levels.
[b]Mid-point inhalation rates are provided in the table for comparative purposes only, the proposed update to the IEUBK model will use the estimated regression equation to calculate inhalation rate as a continuous non-linear function of age.

Table 5. Statistical summary of the non-linear regression model of inhalation rate (m^3/day) on age.

Source	DF	Sum of Squares	Mean Square	F Value	Approx. Pr>F
Model	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Error	[redacted]	[redacted]	[redacted]		
Uncorrected Total	[redacted]	[redacted]			

Inhalation rate parameter estimates.

Parameter	Estimate	Approx. Std Error	Approx. [redacted]% Confidence	
			Lower Limits	Upper Limits
a	[redacted]	[redacted]	[redacted]	[redacted]
b	[redacted]	[redacted]	[redacted]	[redacted]

Table 6. Summary of inhalation rate by age group.

Age Range (months)	N	Inhalation rate (m³/day)						
		Mean	Confidence Limit for Mean		Std Dev	Coeff of Variation	Min	Max
			Lower [redacted]%	Upper [redacted]%				
[redacted]								

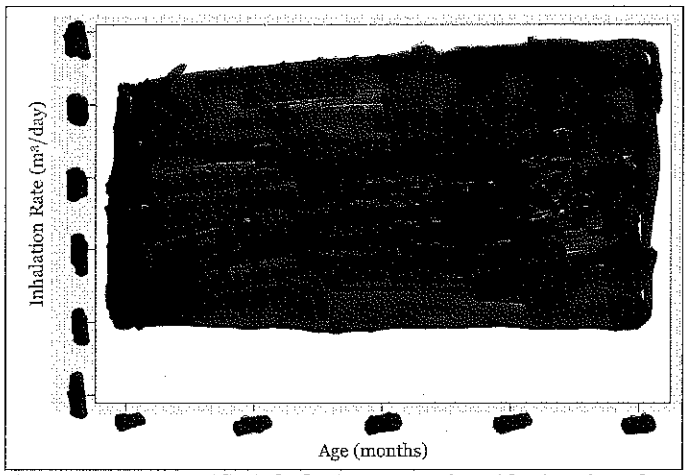

Figure 1. Age-specific inhalation rates (m³/day) using the TEE approach. The regression line is shown with the approximate [redacted]% confidence intervals.

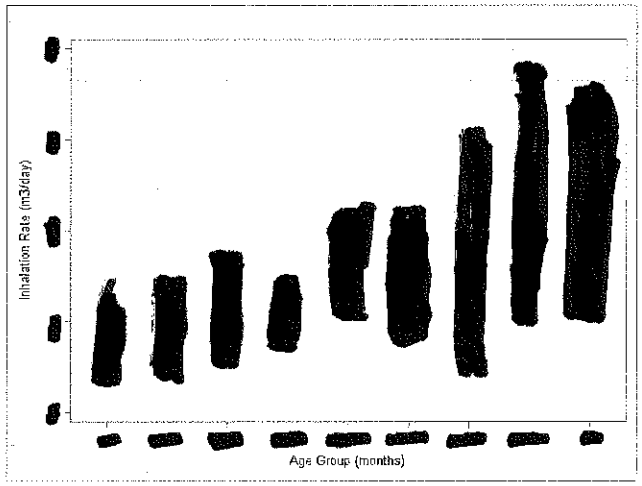

Figure 2. Inhalation rates (m³/day) by age group (months).

Table 7. Comparison of long-term age-specific inhalation rates.

Source	Age Range (months)	Inhalation Rate (m^3/d)	Basis for Age-Specific Value	
IEUBK Default [a]	[redacted]	[redacted]	U.S. EPA, 1989 Phalen et al., 1985	Methodology Time and activity based estimates Data Source Altman and Dittmer 1971, 1972 ICRP, 1975 Nutrition Foundation, 1982
Proposed Inhalation Rates [b]	[redacted]	[redacted]	Layton, 1993 Brochu et al., 2006 Stifelman, 2007	Methodology Total energy expenditure (DLW) Data Source IOM, 2005
U.S. EPA, 1997 [c]	[redacted]	[redacted]	Layton, 1993	Methodology Food-energy intakes Total energy expenditure Data Source USDA/ARS, 1984
U.S. EPA, 2008	[redacted]	[redacted]	Layton, 1993 Arcus-Arth and Blaisdell, 2007 Brochu et al., 2006 Stifelman, 2007	Methodology Food-energy intakes Total energy expenditure (DLW) Data Source USDA/ARS, 1984, 2000 Black et al. 1996 Torun et al. 1996 Butte et al. 2000 IOM, 2005
U.S. EPA, 2011, 2009a	[redacted]	[redacted]	Layton, 1993 Arcus-Arth and Blaisdell, 2007 Brochu et al., 2006 Stifelman, 2007	Methodology Food-energy intakes Total energy expenditure (DLW) Data Source USDA/ARS, 1984, 2000 Black et al. 1996 Torun et al. 1996 Butte et al. 2000 IOM, 2005
U.S. EPA, 2009b	[redacted]	[redacted]		
U.S. EPA, 2010	[redacted]	[redacted]	U.S. EPA, 2008 Layton, 1993 Arcus-Arth and Blaisdell, 2007 Brochu et al., 2006 Stifelman, 2007	Methodology Food-energy intakes Total energy expenditure (DLW) Data Source USDA/ARS, 1984, 2000 Black et al. 1996 Torun et al. 1996 Butte et al. 2000 IOM, 2005

[a] IEUBK Model (v. 1.1, build 11)

[b] Mid-point inhalation rates are provided in the table for comparative purposes only, the proposed update to the IEUBK model will use the estimated regression equation to calculate inhalation rate as a continuous non-linear function of age (see Tables 5 and 6).

[c] The daily inhalation rate is calculated by multiplying the EFD ([redacted] for [redacted] months of age, respectively) by $H^*I_{EQ}^*(m^3/L)$ for those under [redacted] years of age.

UNCERTAINTY

Limitations in the IOM (2005) database preclude making site-specific statistical inferences about inhalation rates in U.S. children. The data used to estimate the regression model were not obtained from a probability sample (IOM, 2005), and the degree to which they are representative of the U.S. population of children less than [redacted] years of age is uncertain. However, the data represent a broad range of U.S. children in regard to age, body weight, height and activity level (IOM, 2005). Layton's approach to calculating age-specific inhalation rates is dependent on the inhalation equivalent ratio (I_{EQ}), which relies on an individual's fitness and energy expenditure levels (U.S. EPA, 2009b). The U.S. EPA (2009b) noted that Layton's (1993) I_{EQ} value of [redacted] may be appropriate for adults, but not necessarily for children.

RECOMMENDATIONS FOR THE IEUBK MODEL

The Exposure Factors Handbook (U.S. EPA, 2011) provides newer inhalation rate data based on the average of four studies (U.S. EPA, 2009; Arcus-Arth and Blaisdell, 2007; Stifelman, 2007; Brochu et al., 2006). Brochu et al. (2006) and Stifelman (2007) are based on the same DLW data, but Arcus-Arth and Blaisdell (2007) and U.S. EPA (2009a) are indirect measures of inhalation rates based on dietary recall and activity-based survey responses. These indirect measures are subject to error, and caution should be exercised when interpreting nutrient assessments based on self-reported dietary data covering only a few days of intake (IOM, 2005).

By contrast, the EE approach is a direct measure to estimate inhalation rate (Brochu et al., 2006; Stifelman, 2007) that is recognized as the gold standard measurement of the total daily energy expenditures. The DLW methodology is, therefore, an improvement over inhalation rate estimates based on dietary recall or activity-based survey data (U.S. EPA 2009b; Stifelman, 2007; Brochu et al. 2006). For this reason, the proposed inhalation rates are preferred for use in the IEUBK model.

The IEUBK model is intended for long-term exposures ([redacted] days, U.S. EPA, 1994a) and estimating long-term average daily EE is the primary advantage of using DLW data (Stifelman, 2007). The TRW Lead Committee recommends using the IOM (2005) DLW dataset and the linear regression equation described in this document to update the inhalation rates in the IEUBK model. Feedback from Regional risk assessors indicates that the regional and ethnic information are not useful because populations move between regions and exposure is not typically ethnically homogenous. The TRW Lead Committee does not believe there is sufficient information for all lead exposure and biokinetic variables, nor is there necessarily a need, to model sex-specific information for typical Superfund site-specific risk assessments. Based on this analysis, the updated values for the inhalation rates are recommended for all applications of the IEUBK model where current and future use scenarios are assessed.

IMPACT ON IEUBK MODEL PREDICTIONS

The proposed inhalation rates increase estimates of daily inhaled air and intake of airborne lead by approximately [redacted] to [redacted]% (depending on age range). At airborne lead concentrations typically input in the IEUBK model (*i.e.*, in the range of [redacted] µg/m³) and with other sources of lead intake, the inspiratory uptake of Pb contributes less than [redacted]% of the total daily lead uptake. The proposed intake values do not have a significant impact on the predicted PbB for any age group, on the geometric mean PbB for all ages, on the probability of the geometric mean exceeding [redacted] µg/dL, or on preliminary remediation goals (PRGs) in the soil Pb concentration range in the interest for OSRTI (Table 8).

The TRW Lead Committee also recommends removing the inhalation rate input from the IEUBK model user interface and making inhalation rate an internal variable of the IEUBK model (See Figure 3).

Table 8. Effects of changing the inhalation rate variable in the IEUBK model.

Source	Age Range (months)							GM†	P_{10}†	PRG† for [redacted]% NTE† µg/dL (ppm)	PRG† for [redacted]% NTE† µg/dL (ppm)
	[redacted]										
Existing default IEUBK model value[a]											
Inhalation Rate (m³/day)	[redacted]										
Lead Uptake from Air (µg/day)	[redacted]										
Calculated Total Lead Uptake (µg/day)	[redacted]										
Calculated Blood Lead Concentration (µg/dL)	[redacted]										
Proposed default IEUBK model value[b]											
Inhalation Rate (m³/day)	[redacted]										
Lead Uptake from Air (µg/day)	[redacted]										
Calculated Total Lead Uptake (µg/day)	[redacted]										
Calculated Blood Lead Concentration (µg/dL)	[redacted]										

†GM: Geometric mean blood lead concentration (µg/dL) for [redacted] month age range; P10: Probability of the predicted GM blood lead concentration ≤ [redacted] µg/dL; PRG: preliminary remediation goal; NTE: not to exceed

[a]IEUBK Model (v. 1.1, build 11)

[b] Mid-point (interpolated) inhalation rates are provided in the table for comparative purposes only, the proposed update to the IEUBK model will use the estimated regression equation to calculate inhalation rate as a continuous non-linear function of age (see Table 4).

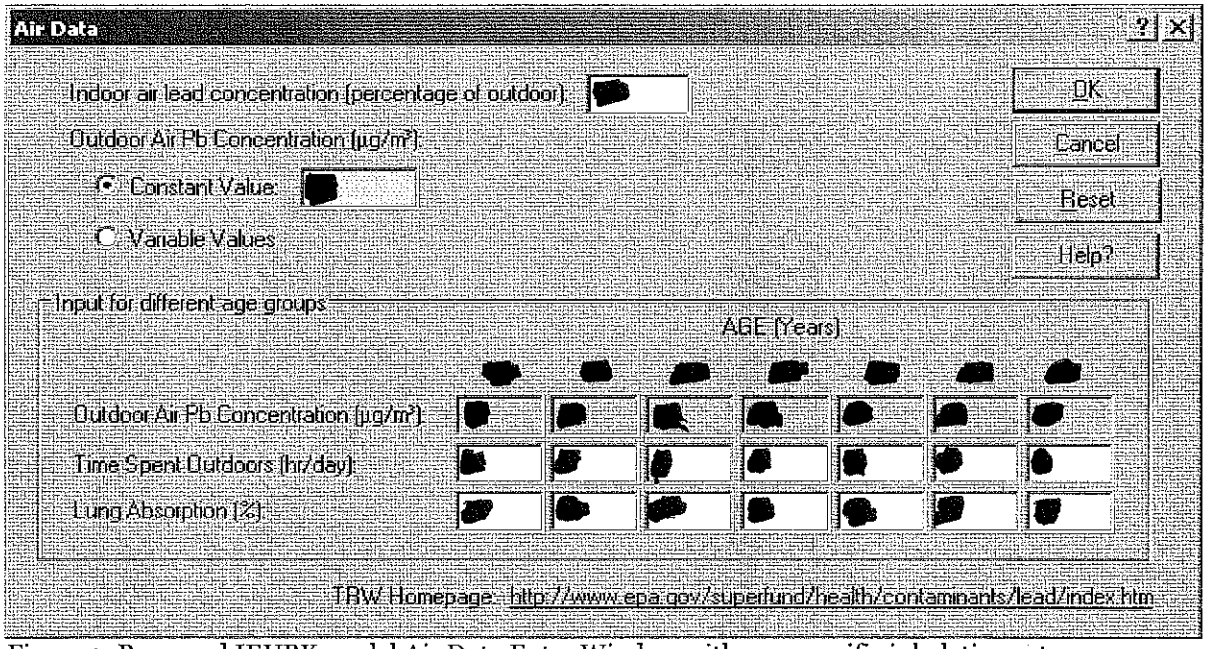

Figure 3. Proposed IEUBK model Air Data Entry Window with age-specific inhalation rates as an internal variable.

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